

**State of California
AIR RESOURCES BOARD**

**Quarterly Report to the California Legislature
on the
Air Resources Board's
Fine Particulate Matter Program**

First Quarter 2000

California Environmental Protection Agency



Air Resources Board

Table of Contents

Executive Summary	1
Introduction.....	2
California Regional PM10/PM2.5 Air Quality Study	4
Health and Exposure Research.....	6
Air Quality Monitoring	6
Emission Inventory Development	9
Air Quality Modeling	12
Planning	12
Control Strategy Development and Implementation	13
Appendix – Summary of Ongoing Particulate Matter Research Projects.....	A-1

Executive Summary

This is the third in a series of quarterly reports to the Legislature on the Air Resources Board's (ARB) fine particulate (PM_{2.5}) program required in fiscal year 1999-2000 budget language. This report provides background on ARB's particulate programs, and covers ARB's recent accomplishments and planned activities in program areas including health and exposure research, air quality monitoring, emission inventory development, air quality modeling, planning, and control strategy development. This report includes activities funded through specific legislative appropriations, as well as programs funded through ARB's budget.

In general, we provide a retrospective look at the last quarter (January through March) and a look forward at the upcoming quarter (April through June). In each report, we will also highlight selected programs, providing additional background to put expected future activities in context. In this report, we highlight our monitoring activities and some of our findings from reviewing recently collected PM_{2.5} air quality data. Key activities from the first quarter include:

- In February, the Board approved lower emission standards for transit buses which will significantly reduce emissions of nitrogen oxides (NO_x) and toxic diesel particulate exhaust over the next ten years by requiring cleaner engines, cleaner diesel fuel, retrofits to reduce particle emissions from older diesel buses, and a phase-in of zero emission buses. The regulation allows transit agencies to choose between a diesel or alternative fuel path to lower emissions. By 2007, every transit bus on the road will be at least 85 percent cleaner as a result of this regulation.
- In January, the Board adopted lower emission standards for off-road diesel equipment engines. These standards will be phased in beginning this year. These regulations will reduce emissions of NO_x and include provisions to add tighter particulate matter standards in the future if technologically feasible.
- In January, we presented an evaluation of PM_{2.5} air quality in California at the Air and Waste Management Association's *PM2000: Particulate Matter and Health* Conference in Charleston, South Carolina. In California's urban areas, annual mean concentrations of PM_{2.5} range from 10 to 25 micrograms per cubic meter (µg/m³) compared to the federal annual PM_{2.5} standard of 15 µg/m³. Observed 24-hour average peaks reach levels as high as 160 µg/m³ compared to the 24-hour federal PM_{2.5} standard of 65 µg/m³. Annual concentrations have declined at most urban sites in California since monitoring began in 1989. The declines are especially pronounced for the nitrate and sulfate components of PM_{2.5}, and are likely related to corresponding reductions in emissions and ambient levels of NO_x and sulfur oxides (SO_x). Annual average concentrations for PM_{2.5} in background areas range from 2.5 to 5 µg/m³, with the lower value representing the best estimate of PM_{2.5} concentrations in the absence of man-made emissions.

Introduction

Particulate matter pollution is one of the most formidable air quality and public health issues facing California. Exposure to particle pollution is linked to increased frequency and severity of asthma attacks and bronchitis, and even premature death in people with existing cardiac or respiratory disease. Those most sensitive to particle pollution include people with existing respiratory and cardiac problems, children, and the elderly. Prolonged and repeated exposure can also have adverse impacts. All inhalable particles are harmful – both “coarse” particles over 2.5 microns to 10 microns in diameter and “fine” particles, those 2.5 microns or smaller.

Virtually all of California violates the state air quality standards for inhalable particulate matter less than ten microns (PM10), which includes the subset of fine particles. Several areas, both urban and rural, also violate the federal PM10 air quality standards. In 1997, U.S. EPA promulgated new federal air quality standards for fine particulate matter 2.5 microns or less in diameter (PM2.5) to complement the existing PM10 standards. The PM2.5 standards have focused attention on understanding the nature of particle pollution and finding ways to reduce it.

Under the federal Clean Air Act, states must develop plans, known as State Implementation Plans (SIP), describing how and when they will attain national ambient air quality standards. With ARB technical support, the districts prepared the required PM10 SIPs. We expect PM2.5 SIPs to be due in the 2006 to 2007 timeframe. While state law does not require local districts to prepare plans for attaining the state PM10 standards, our statewide program to reduce ozone also reduces particulate levels.

The PM2.5 standards have been challenged in court by the American Trucking Association and a number of other business and industry groups. In May 1999, a three judge panel of the U.S. Court of Appeals for the District of Columbia returned the standards to U.S. EPA to provide a better rationale for how it selected the particular levels of the standards. U.S. EPA and the Department of Justice appealed that ruling to the full Court of Appeals, but the court declined to reconsider the case. In January, U.S. EPA and the Department of Justice filed a request for the Supreme Court to review the case. U.S. EPA expects a decision by April on whether the Supreme Court will hear the case. If the Court hears the case, its final ruling would likely come in Spring 2001. Although the PM2.5 standards remain in place, the court has prohibited U.S. EPA from implementing them. We expect that the standards will ultimately be implemented, either because U.S. EPA prevails before the Supreme Court or the agency provides the clarification requested by the Court of Appeals.

Unlike ozone, which is a single chemical compound, particulate matter is a complex mixture of many different species generated from a wide array of sources. Particulate matter can be either directly emitted into the air in forms such as dust and soot, or it can be formed in the atmosphere (like ozone) from the reaction of gaseous precursors such as nitrogen oxides (NOx), volatile organic compounds (VOCs), sulfur oxides (SOx), and ammonia. NOx and VOCs are also precursors of ozone pollution.

Directly emitted particles are called “primary particles,” while those formed in the atmosphere are referred to as “secondary particles.” During some episodes of elevated particle levels in California, ammonium nitrate – formed secondarily from NO_x and ammonia emissions – can account for over half of the PM_{2.5} mass. Understanding how particulate ammonium nitrate is formed and how to effectively reduce it through controls on NO_x and/or ammonia sources is a critical part of California’s PM_{2.5} program.

Sources of ambient particulate matter include: combustion sources such as trucks and passenger cars, off-road equipment, industrial processes, residential wood burning, forest/agricultural burning, fugitive dust from roads, construction, mining, and agricultural activities and ammonia sources such as livestock operations. In general, combustion processes form fine particles, whereas particles such as dust tend to fall in the coarse range. Diesel vehicles are a significant source of particle pollution from the motor vehicle fleet. Because ozone and particulate matter pollution are caused by many of the same sources and precursors, many of the control strategies in California’s Ozone SIP – particularly NO_x controls – provide dual benefits for public health by reducing particulate matter as well.

In the last decade, ARB has enhanced its technical and research program for particulate matter, building the scientific foundation for the PM₁₀ SIPs adopted in the mid-1990s. ARB is now undertaking significant additional particulate matter work, including: health and exposure research; expanded air quality monitoring; emission inventory improvement; development of improved air quality models; and comprehensive field studies. Each of these technical areas plays an important role in developing California’s SIP to address the federal PM_{2.5} standards and strategies to meet the state standards:

- *Health and exposure research* helps us understand both the impact of exposure to air pollutants (including who is susceptible to injury and the mechanisms of injury) as well as who is exposed, for how long, when, and where.
- *Air quality monitoring* provides information on which areas violate the standards and the nature and extent of the problem.
- *Emission inventories* provide an accounting of the sources of particulate matter emissions and the quantities of emissions produced from these sources.
- *Air quality models and data analysis* link air quality monitoring and inventory data with information on meteorology and atmospheric chemistry to tell us the relationship between emissions and air quality. Once we know this relationship, we can determine how much we need to reduce emissions to meet the air quality standards. We also use modeling to understand how air pollution is transported between regions. In support of our modeling efforts, we undertake extensive field studies to obtain the intensive meteorological, emissions and air quality data needed to run the models.

- *Clean air plans* describe how and when we will attain air quality standards. Plans include the technical foundation of monitoring data, emission inventories, and air quality models, as well as a control strategy for reducing emissions.
- *Control strategy development and implementation* is the critical step. Many ARB regulations provide multiple benefits. Because they reduce emissions of both ozone and PM_{2.5} precursors, these controls provide dual benefits for public health. In this step, we consider technical feasibility and cost-effectiveness as well as the socioeconomic and environmental impacts.

This report covers ARB's recent accomplishments and planned activities in each of these program areas. In addition, an appendix to the report contains brief summaries of ongoing research projects.

Our program to characterize and control PM_{2.5} is closely related to two other ARB programs: the particulate diesel exhaust risk management efforts and regional haze program. In 1998, ARB identified particulate emissions from diesel-fueled engines as a toxic air contaminant (TAC). We estimate the statewide average potential lifetime cancer risk from breathing particulate matter from diesel-fueled engines to be 450 chances in a million (considering indoor exposure and outdoor exposure), which represents a significant threat to public health. We are now evaluating ways to reduce the risk associated with exposure to particulate emissions from diesel engines. These risk management efforts dovetail with existing efforts to control emissions to attain the particulate matter and ozone air quality standards.

In 1999, U.S. EPA finalized its new program to reduce the regional haze that impairs visibility in many national parks and wilderness areas. Because fine particles are a main contributor to visibility impairment, our particulate matter control program will improve visibility as well. U.S. EPA intends to align the timelines for PM_{2.5} and regional haze planning so that the necessary technical work can be coordinated.

California Regional PM₁₀/PM_{2.5} Air Quality Study

The \$27 million California Regional PM₁₀/PM_{2.5} Air Quality Study will provide much of the key technical information needed to develop PM_{2.5} SIPs and additional particulate reduction strategies for the San Joaquin Valley and surrounding areas. This is the largest particulate matter technical study ever undertaken. Study objectives include:

- enhancing our fundamental understanding of mechanisms of particulate formation and transport;
- developing and demonstrating methods useful in formulating candidate control strategies for attaining PM₁₀ and PM_{2.5} standards in central California; and

- providing reliable means for estimating the impacts of control strategies developed for PM₁₀/PM_{2.5} on visibility, air toxics, and acidic aerosols and on attainment strategies for other pollutants, notably ozone.

The start of a 14-month field program last December marks a major milestone for the study. In order to address the diversity of the particle pollution problem in central California, the field program is divided into several different elements. These include: (1) a long-term program from December 1999 through January 2001; (2) a summer field program to assess visibility in the southeast desert; (3) a fall episodic program in September and October of 2000; and (4) a winter episodic program in December and January of 2000/2001. Because different conditions and different sources lead to elevated particle levels in the fall and winter seasons, we are planning specific intensive monitoring programs targeting each season. The long-term program will characterize annual average concentrations and their causes. (Both annual and 24-hour particulate matter levels in the Valley violate the air quality standards.)

The field program is being conducted over a domain extending from the Pacific Ocean on the west into the Mojave Desert on the east, and from the upper Sacramento Valley on the north to the Tehachapi Mountains in the south. The field program will provide an extensive database to support data analysis and air quality modeling for use in developing plans to attain the particulate matter standards. In addition to the monitoring program, an extensive emission inventory improvement effort is underway. The improved inventory is needed for future modeling efforts and evaluations of potential control strategies.

First Quarter 2000 Update

- **Phase-in of the Annual Field Monitoring Program Completed.** During the first quarter, we installed all monitoring equipment and conducted field audits. In addition, we constructed the 100 meter meteorological and air quality monitoring tower at Angiola and equipped it with meteorological instrumentation. The monitoring network consists of five anchor sites, 44 satellite sites, five surface meteorological sites, and eight upper air meteorological sites. We also continued coordinating our monitoring program with the measurements being collected at the U.S. EPA supersite in Fresno.
- **Planning for Summer, Fall, and Winter Field Programs.** We are continuing to plan the measurements to be collected during special summer, fall, and winter studies. Experience gained from initial deployment and operation of the annual field program is being used to refine the measurements to be collected during these upcoming programs. We expect to finalize our plans for these programs and begin awarding contracts for the work during the second quarter of this year.
- **Database System.** We have finished designing a database management system that will be used to archive the comprehensive air quality and meteorological data being collected during the field program.

- **Emission Inventory Projects.** We have developed workplans for two emissions inventory projects to be conducted during the field program. The first will collect detailed activity data associated with emissions events that occur during the field programs. The second will develop improved chemical speciation profiles for key sources of organic particulate matter. In addition, we also developed a request for proposal for a project to prepare a spatially-resolved ammonia inventory for the study region.
- **Upcoming Start of Summer Field Program.** The summer field program to assess visibility in the southeast desert will commence on June 15 and run through September 15. Initial activities during the second quarter will include instrument purchase and checkout, site setup, and the initiation of monitoring.

Health and Exposure Research

ARB has long recognized that particulate matter is harmful and has taken a lead in research to more clearly define how particle pollution impacts the health of Californians. Extensive research programs are underway both nationally and within California to clarify some of the uncertainties regarding who is at risk, whether a truly safe level of particulate matter can be determined, the mechanism of injury and the role of specific components of particulate matter in producing harmful health impacts. ARB is also a leader in research on exposure to particles and their toxic components in indoor, outdoor, and in-vehicle environments. We also publish practical guidelines on how to reduce personal exposures to indoor and outdoor pollutants, including particles.

The ongoing particulate matter health and exposure studies being funded by ARB are highlighted in the appendix to this report. In future reports, we will provide updates on these studies as they reach significant milestones and on new studies we fund or conduct.

Air Quality Monitoring

California's air quality monitoring program provides information used to determine which areas violate standards, characterizes the sources that contribute to pollution, assesses pollution transport, and supports health studies and other research. Monitoring data also provide the ultimate check on how effective our programs are – is the air quality improving? California already has a PM10 air monitoring network with over 150 monitors located throughout the state. To assess the nature and extent of the PM2.5 problem in California, ARB and local air districts are enhancing and expanding the PM2.5 monitoring program. ARB is augmenting the existing PM2.5 monitors with new federally approved PM2.5 monitors to measure particle constituents. This effort began in 1998 and will continue for several years until our network is fully deployed. As the first step in deploying this new network, we have already placed federally approved PM2.5 mass monitors at about 75 sites across California.

Speciation monitoring provides valuable information about the composition (and ultimately sources) of PM_{2.5} pollution. However, monitoring of the individual species that make up particulate matter is still an emerging field, with continuous speciation measurements the greatest challenge. To develop the best speciation network, California will need to take full advantage of emerging technologies – including instrumentation that is not yet commercially available. We are participating in the development of new sampling technology and critical research in this field, including special studies to evaluate newly emerging methods not currently used in routine monitoring. With previously allocated funds, we are deploying the first round of equipment. We will phase in the remaining speciation and continuous monitors through 2001 to allow additional time to assess which technologies are the most effective.

First Quarter 2000 Update

- **PM_{2.5} Speciation Network Design and Deployment.** We are continuing to refine the design of our PM_{2.5} speciation network. In the last quarter, we completed the following tasks.
 - We have deployed PM_{2.5} speciation monitors at three of the U.S. EPA required sites in California. The sites are located in Fresno, Sacramento, and San Jose, and the instrument being used is the Spiral Aerosol Speciation Sampler (SASS). Data collected at these sites will be used to support the California Regional PM₁₀/PM_{2.5} Air Quality Study and also a “mini-trend” study being conducted by U.S. EPA. The goal of the trend study is to evaluate different sampling methods. At the Fresno site, we installed a Reference Ambient Air Sampler to operate in parallel with the SASS monitor. Information from each of these sites and samplers will be critical for our selection of samplers that best serve our network needs.
 - We are purchasing 48 new generation continuous PM_{2.5} mass and speciation monitors, employing seven different sampling technologies. These advanced technology samplers consist of: 29 continuous PM_{2.5} mass monitors employing beta attenuation monitoring (BAM) technology (14 will be deployed along both sides of the California/Mexico border and are funded through the federal Border Grant), seven portable battery powered nephelometers which measure continuous PM_{2.5} mass, seven continuous nitrate analyzers which provide continuous measurements of the nitrate fraction of fine particulates, one continuous carbon analyzer which measures the carbon fraction of particulate matter, one field ion chromatograph which allows continuous analysis of particulate species (such as nitrate, ammonium, and sulfate), one PM_{2.5} nephelometer to measure continuous PM_{2.5} mass, and aethalometers for the continuous measurement of particulate carbon. Of these 48 monitors, three have been received, purchase orders have been issued for 36 and we are awaiting delivery, and purchase orders are pending for nine.

- **Data Analyses.** We have conducted several data analyses related to PM_{2.5}. Results of these analyses, summarized below, provide us with a better understanding of the nature and causes of the fine particle problem in California.

- *Evaluation of PM_{2.5} Air Quality in California.* In January, we presented a paper at the Air and Waste Management Association's *PM2000: Particulate Matter and Health* Conference in Charleston, South Carolina. The conference was the last opportunity to submit research findings to peer review for U.S. EPA's consideration in its current review of the science supporting the particulate matter standards, scheduled to be completed by 2002.

It will be several years before our recently deployed network of PM_{2.5} Federal Reference Method (FRM) samplers produces information on long-term trends. However, California has a rather unique opportunity to look at historical records because we have routinely collected data on PM_{2.5} and its major constituents for the past decade. Because the networks are located at many of the same sites, we have begun to establish relationships between our pre-existing PM_{2.5}, PM₁₀, California Acid Deposition Monitoring Program, and Children's Health Study samplers and the new network of PM_{2.5} FRM samplers. Based on 1996-1998 air quality data from California's pre-existing PM_{2.5} monitors, annual mean concentrations of PM_{2.5} in California's urban areas range from 10 to 25 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) compared to the federal annual PM_{2.5} standard of 15 $\mu\text{g}/\text{m}^3$. Annual average concentrations for PM_{2.5} in background areas range from 2.5 to 5 $\mu\text{g}/\text{m}^3$, with the lower value representing the best estimate of PM_{2.5} concentrations in the absence of man-made emissions. Through 1999, observed 24-hour average peaks reach levels as high as 160 $\mu\text{g}/\text{m}^3$ compared to the 24-hour federal PM_{2.5} standard of 65 $\mu\text{g}/\text{m}^3$. Each 10 $\mu\text{g}/\text{m}^3$ increase in daily PM concentrations is associated with about a one percent increase in natural mortality, so the relatively high peak values are a serious health concern.

Annual average concentrations have declined at most urban sites in California since monitoring began in 1989. The declines are especially pronounced for the nitrate and sulfate components of PM_{2.5}, and are likely related to corresponding reductions in emissions and ambient levels of NO_x and SO_x.

- *Evaluation of Air Quality and Visibility in National Parks.* We performed an analysis of annual average PM_{2.5} concentrations at all eleven California stations in the Interagency Monitoring of Protected Visual Environments (IMPROVE) network for regional haze in national parks and wilderness areas. Annual PM_{2.5} concentrations varied from as little as 2.5 $\mu\text{g}/\text{m}^3$ at Lassen and Redwood National Parks to as high as 10 $\mu\text{g}/\text{m}^3$ (a significant fraction of the national standard of 15 $\mu\text{g}/\text{m}^3$) at San Geronio Wilderness

which is downwind of urban Los Angeles. We found that low secondary aerosol and elemental carbon contributions are characteristic of the cleaner sites, and greater organic carbon fractions are seen at the sites with higher concentrations.

- *Expansion of Visibility Monitoring Network.* The IMPROVE network is being expanded nationwide to address U.S. EPA's new regional haze program. To support this effort, we reviewed the existing and proposed new sites in the IMPROVE network to determine whether relative humidity sensors should be added to these sites. Relative humidity measurements are needed as part of the calculation which relates the PM_{2.5} and species concentrations measured by the IMPROVE samplers to the measure of visibility impairment. Of the 19 IMPROVE sites in California, we recommended that seven of the key sites be equipped with relative humidity instruments.
- **Data Management.** PM_{2.5} data are now available to the public on our website at <http://www.arb.ca.gov/aqd/aqd.htm>. Available information includes a listing of the mass measurements for each site (measurements are made every sixth day, third day, or daily, depending on the sampling schedule for the site). We are continuing to develop summary tables and should complete them during the second quarter of 2000. The summary tables will include for each calendar year at each site, the top four measurements and the number of days over the 24-hour PM_{2.5} standard. In addition, we plan to provide interactive web access to make the data more broadly accessible.
- **2000 California Particulate Matter Monitoring Network Description.** We are gearing up for our year 2000 PM network plan that is due to U.S. EPA by July 1. We are coordinating closely with the local districts, and U.S. EPA to produce the plan. As part of the plan development, we will be reviewing the deployment status of equipment funded during 1998 and 1999. We will also be analyzing the data that have been collected thus far. Our focus for this year's plan will be on designating certain sites in our core network as "National Air Monitoring Stations," which are part of the nationwide network to establish long-term PM_{2.5} trends. Such designation is required under federal regulations. In addition, we will continue our work in designing a PM_{2.5} speciation network for California.

Emission Inventory Development

Over the last year, ARB has embarked on a program to identify and characterize the sources of emissions of PM_{2.5} and its precursors. This work will lead to the development of a statewide inventory of the emissions and sources of PM_{2.5}. The inventory will include estimates of future emissions, which consider growth and the benefits of adopted air quality programs. By accurately quantifying PM_{2.5} emission sources, we can better target our control strategies.

ARB's existing emission inventory includes particulate emissions estimates for directly emitted PM10. Our inventory also includes estimates for gaseous precursors, such as NOx, SOx, and VOCs. We are now incorporating emission estimates for PM2.5, as well as additional particulate precursors such as ammonia. Because PM2.5 emissions are difficult to measure and characterize, this will be a multi-year effort. By 2001, we intend to produce draft emission inventories for PM2.5 and ammonia, which can be used for identifying the most important sources of PM2.5 air pollution. These inventories are being developed in coordination with the air districts, air agencies in other states, U.S. EPA, industry, and researchers.

ARB funds a number of projects to quantify and better understand PM2.5 emissions from stationary, area, and mobile sources. These are summarized briefly in the appendix to this report.

In addition, ARB is taking over the operation of the chassis dynamometer testing facility originally managed by the Los Angeles Metropolitan Transit Authority. This facility will be used to perform both engine- and chassis-based emissions tests (including PM2.5) of heavy-duty vehicles on a regular basis. (Chassis dynamometers are treadmill-like devices that test engine-vehicle combinations. Engine dynamometers test engines that have been removed from, or are not yet installed in, vehicles.) The use of chassis dynamometers that accommodate trucks and buses will allow us to measure in-use emissions from these vehicles. Previously, we had only very limited opportunities to make these types of measurements. Data will be used to update the emission inventory.

First Quarter 2000 Update

- **Coordination with Other Agencies.** To help in coordinating California's efforts with other states, regions, and agencies, we participated in several meetings during the last quarter regarding our PM inventory efforts. We made presentations at the monthly meetings of the San Joaquin Valley Agricultural Technical Group to discuss research related to agriculture and air quality. We also participated in a national workshop, held in Sacramento, that was organized by the Agricultural Research Service of the U.S. Department of Agriculture (USDA). The purpose of the workshop was to identify and prioritize research needs related to the effects of agriculture on air quality, and the effects of air quality on agriculture. Finally, we organized and led a workshop that included national experts in the area of biogenic emissions. Biogenic emissions from plants have the potential to contribute to both particulate and ozone formation, so it is important to better understand these emissions. We will continue these coordination efforts and plan to meet with U.S. EPA and USDA during the second quarter to discuss ammonia emission inventory development.
- **Ammonia Inventory Development.** We have developed a methodology for estimating ammonia emissions from beef and dairy cattle. In February, we met with representatives from industry and academia to get their feedback on our

proposed method. The proposed method helped to emphasize the need for additional California-specific research to better understand beef and dairy cattle emissions. Of most concern to those who attended the meeting was the high level of uncertainty in the per-animal ammonia estimates which range from 20 to 130 pounds per animal. We agreed to delay finalizing the methodology for several months while additional testing is being performed. Those present also agreed to work with us to refine our animal population estimates. In the upcoming quarter, we will develop a long-term plan for creating the ammonia inventory, and we will continue developing ammonia emission estimates.

- **New Research Projects for FY 1999-2000 Selected.** We have developed four research project concepts for FY 1999-2000 to better understand PM2.5 emissions from stationary and area sources, as well as visibility reducing emissions. We have identified qualified prospective researchers within the University of California system to perform the work; final workplans are being developed. We will finalize contracts during the second quarter. Work will begin on the contracts no later than July 1. A summary of each project, the research organization, and approximate cost are listed below.
 - **Vehicle travel on unpaved roads:** This project will provide better estimates of vehicle activity on unpaved roads within California. This information will help to correct deficiencies in how unpaved road dust estimates are currently calculated and will aid in producing more effective dust control strategies. Contractor: UC Davis. Cost: \$90,000
 - **Evaluation of geologic dust near emission sources:** Based on analysis of ambient air, it appears that existing estimates of particulate matter emissions from dust sources may be too large. This project will explore how the dust from sources such as unpaved roads and agricultural fields travels in the air and how long it stays suspended. This work will help us better understand the contribution of dust sources to regional particulate levels. Contractor: UC Riverside. Cost: \$240,000
 - **Emissions from wood-burning stoves and fireplaces:** This project will develop better estimates of particle and precursor emissions from woodstoves and fireplaces by improving our understanding of when and where these emissions occur. Contractor: UC Berkeley. Cost: \$90,000
 - **Emissions from agricultural burning:** This project will evaluate and improve the methods used in California to estimate particulate and other emissions from burning prunings and other agricultural residues. This work will be coordinated with industry representatives and burn managers to help us better quantify the impacts of agricultural burning. Contractor: UC Berkeley. Cost: \$90,000

Air Quality Modeling

ARB develops air quality models and runs these models to predict how emissions, weather, and terrain influence ambient levels of pollutants, based on monitoring data, emission inventories, and atmospheric chemistry. Air quality models are also used to determine the emission reductions needed to achieve air quality standards and to evaluate the effectiveness of control strategies. Regional models are used to assess pollution transport from one area to another. These types of transport assessments are needed to ensure that necessary actions are taken in both upwind and downwind districts to meet air quality standards.

California has developed some of the most advanced photochemical models in the nation for ozone. However, the state of modeling is not as advanced for particulate matter, in part because of a lack of the extensive air quality and meteorological data needed to run modeling simulations. We are working to advance the state of particulate matter modeling for use in developing PM_{2.5} attainment plans and particulate matter control strategies. Data collected during the California Regional PM₁₀/PM_{2.5} Air Quality Study field program will be used to evaluate and improve the performance of our meteorological and air quality models.

For attainment planning, the PM_{2.5} modeling analyses must show the “carrying capacity,” or how many tons of emissions each affected area can hold before it exceeds the daily or annual PM_{2.5} standards. The carrying capacity for PM_{2.5} and precursors determines the type and amount of emission reductions needed from new control measures. PM_{2.5} models will also form the basis for regional haze models to assess the impact of our control strategies on visibility in California and in downwind states.

Planning

The timeline for developing PM_{2.5} attainment plans (SIPs) is dictated by when nonattainment areas are designated, which in turn is dictated by when sufficient PM_{2.5} air quality monitoring data are available. Although California had a small pre-existing PM_{2.5} monitoring network, no nationwide PM_{2.5} monitoring network or federally approved monitor for measuring PM_{2.5} existed when the new federal standards were promulgated in 1997. In 1999, we began collecting PM_{2.5} monitoring data using the federal reference method for comparison to the standards. Three years of monitoring data are needed to designate areas as attainment or nonattainment. In addition, when U.S. EPA promulgated the PM_{2.5} standards, it agreed to complete its next health review of the standards prior to designating areas. That review is scheduled to be finished in 2002. Thus, we expect nonattainment areas will be designated in 2003, at the earliest. SIPs would then be due three years later – or 2006 at the earliest. In the meantime, PM₁₀ nonattainment areas will continue implementing their PM₁₀ SIPs. Many of the strategies in these plans reduce PM_{2.5} as well because PM_{2.5} is a part of PM₁₀.

This schedule is still tentative – in part, due to an ongoing legal challenge to the new standards. Because the planning timelines are relatively long and deployment of the monitoring network is not being delayed, it is likely that the legal challenge will be resolved without ultimately delaying the schedule for submitting PM2.5 SIPs. Once the court case is resolved, U.S. EPA will issue guidance detailing the specific planning requirements and timelines for the PM2.5 standards.

For regional haze, U.S. EPA intends to require visibility SIPs at the same time as PM2.5 SIPs. The new regional haze regulation also provides an alternative approach for the nine states which participated in the Grand Canyon Visibility Transport Commission (including California). These states may choose to pursue an accelerated plan submittal in 2003, based on the Commission's recommendations for improving visibility at the Grand Canyon. We expect to pursue both approaches. We will coordinate with other western states as we develop a regional haze SIP in 2003 to address our contribution to visibility impairment in the Grand Canyon region. We will address visibility concerns for national parks and wilderness areas in California in coordination with our PM2.5 SIP in the 2006 timeframe.

First Quarter 2000 Update

- **South Coast Ozone Plan Revision.** In January, ARB approved an interim revision to the South Coast Air District's SIP to meet the federal one-hour ozone standard. U.S. EPA has also proposed approval of the plan and expects to take final action in April. The revision strengthens the District's control strategy compared to its 1997 plan, providing additional near-term emission reductions and reflecting the District's adoption of over 150 tons per day of new emission reductions since 1994. The District's PM10 plan relied on the ozone SIP measures, so the revision reinforces the PM10 plan by providing the needed emission reductions earlier. This revision is an interim step before a comprehensive revision to state and local control strategies planned for 2001. The comprehensive revision will consider the particulate matter benefits of changes to the ozone strategy.

Control Strategy Development and Implementation

ARB develops control strategies for stationary, area, and mobile sources to reduce emissions and achieve air quality goals. The development of control strategies is based on emission inventories and modeling data, considering the need for additional reductions to meet state and federal requirements, existing controls, and technical feasibility. Control strategies are also evaluated for cost-effectiveness, and socioeconomic and environmental impacts. Our assessment of the controls needed to attain state and federal standards will include estimating the PM2.5 benefits from current and planned control programs for PM10 and ozone.

In addition to regulations, we are pursuing emission reductions from voluntary programs, such as the Carl Moyer Program. This program provides grants for the

incremental cost of cleaner trucks, buses, boats, agricultural equipment, and other diesel engines. The program is designed to reduce NOx emissions (which provide dual benefits for ozone and PM2.5); however, many of the projects also reduce direct particulate matter emissions. For example, projects that replace diesel engines with natural gas engines reduce NOx and eliminate diesel particulate emissions. The program seeks to accelerate emission reductions from diesel engines by providing grants to cover part of the cost of purchasing cleaner engines.

We are reviewing all mobile source categories to determine the potential for additional emission reductions. Potential measures will be identified for the next revision to California's Ozone SIP. Although the focus of our next comprehensive clean air plan will be ozone, we will also consider the impact of future mobile source measures in reducing particle as well as ozone pollution. We plan to present a comprehensive revision to our statewide ozone control strategy to the Board in 2001.

Efforts to develop and implement control strategies to meet particulate matter air quality standards relate closely to our efforts to characterize and manage the risk associated with toxic particulate emissions from diesel engines. To assist with our risk management activities, we formed an Advisory Committee of representatives from industry, environmental groups, government agencies, and the public. We are developing a "needs assessment" to: identify the current public health impact of particulate emissions from diesel-fueled engines; assess the effectiveness of programs currently in place; and determine what technically and economically feasible strategies could be pursued to further reduce emissions. We are also developing guidelines to assist the districts in permitting new and modified stationary sources that operate diesel-fueled engines. We expect to finalize both reports in Fall 2000.

First Quarter 2000 Update

- **Transit Bus Standards.** In February, the Board approved lower emission standards for transit buses which will significantly reduce emissions of NOx and toxic diesel particulate exhaust over the next ten years by requiring cleaner engines, cleaner diesel fuel, retrofits to reduce particulate matter emissions from older diesel buses, and a phase-in of zero emission buses. The regulation allows transit agencies to choose between a diesel or alternative fuel path to lower emissions. By 2007, every transit bus on the road will be at least 85 percent cleaner as a result of this regulation.
- **Off-Road Diesel Equipment Engine Standards.** In January, the Board adopted lower emission standards for off-road diesel equipment engines. These standards will be phased in beginning this year – several years earlier than anticipated in the 1994 Ozone SIP. These regulations will reduce emissions of NOx and include provisions to add tighter particulate matter standards in the future if technologically feasible. In addition, more stringent particulate matter standards for diesel off-road engines will be considered in a technical review to take place in 2001.

- **Smoke Management Regulations.** In March, the Board will consider modifying ARB's smoke management regulations (particulate matter is a significant component of smoke). These changes are meant to reduce the impacts of smoke from crop and forestry burning. Most of the changes address the use of "prescribed" fire in forests or rangelands. The regulatory changes will require consideration of the cumulative impacts of all fires within an airshed; increased coordination between air quality, fire agencies, State and federal land managers, farmers and ranchers, both within and between airsheds; and ensure that prescribed burners evaluate and use techniques to minimize smoke.
- **Carl Moyer Program.** A 13-member Advisory Board is evaluating whether funding for the Carl Moyer Program should continue and, if so, at what level. To date, the program has been funded with one-time State appropriations of \$25 million for FY 1998-99 and \$23 million for FY 1999-00 (\$19 million for heavy-duty engine projects and \$4 million for infrastructure and advanced technology development). Local air districts administer the program and must provide a one dollar match for every two dollars of State funds. The program has been well-received with demand for project funding about three times the available funding. The Advisory Board's final report is due to the Governor and the Legislature by the end of March.
- **Clean Diesel Fuel for Locomotives.** We are evaluating a strategy that would require locomotives refueling in California to use California clean diesel fuel. This measure would reduce emissions of both nitrogen oxides and particulate matter. We expect to bring a proposal to the Board in June.
- **Air Quality and Agriculture Forum.** In our last report, we stated that we had planned to hold a public forum in Fresno on air quality and agriculture on February 7. In response to significant interest from the agricultural community, we are expanding the scope of the forum and rescheduling it for June (tentatively June 8) in Tulare. The revamped forum will explore research, planning, and emission reduction activities at the local, state, and federal level.
- **Heavy-Duty Vehicle Roadside Inspection Program.** Under the Heavy-Duty Vehicle Inspection Program, inspectors conduct random roadside tests of diesel trucks to ensure that smoke emissions are within acceptable levels and that emission control devices have not been tampered with. Owners of failing vehicles are issued citations and required to make repairs. Through the end of January, we have inspected over 33,000 vehicles since the program was restarted in June 1998 (with over 2,000 inspections since our last report). The total inspections have resulted in more than 2,100 citations and 600 non-penalty "fix-it" tickets. The failure rate has decreased from 11 percent when the program was first restarted to a current 8.3 percent. More than 1,800 trucks and buses have been repaired to date. We have instituted a formal program to pursue those owners who are delinquent in clearing their citations in order to ensure that repairs are made. Industry acceptance of the program is good, as indicated by

the low rate of citation appeals – just over two percent. The penalties that we collect through the inspection program are recycled back to the industry in the form of incentive programs that promote cleaner heavy-duty engines.

- **Periodic Self-Inspection Program.** The Periodic Self-Inspection Program requires all California fleets with two or more trucks or buses to perform annual smoke and anti-tampering inspections and repair failing vehicles. The first annual self-inspections of heavy-duty diesel-powered vehicle fleets had to be completed by October 1. Through the end of January, we have conducted 825 fleet audits and found a compliance rate of 49 percent. We are working with owners of noncomplying fleets to bring their fleets into compliance.

Appendix

Summary of Ongoing Particulate Matter Research Projects

Health Effects and Exposure Research Projects

- **Children's Health Study:** This major epidemiological study follows the lung development and respiratory health of approximately 5,000 school children from 12 southern California communities in 4th through 12th grades. The study will continue through 2003.
- **Cardiovascular Health Study:** This study evaluates how air pollution, including particulate matter, impacts the well-being of a group of elderly people, especially as related to their cardiac health status.
- **Health Impacts of Smoke:** This study evaluates the respiratory health impacts experienced when people breathe smoke from burning such common materials as rice straw, wood wastes, and wood used to heat homes.
- **Toxicological Studies of Particles:** Studies are underway in which rats are exposed to synthetic components of ambient particulate matter. These studies are evaluating cellular and tissue responses to these components, and how factors such as animal age and particle size affect observations. We hope this research will provide information on the physiological mechanisms that produce the adverse impacts observed in community health studies.
- **Kaiser Hospital Study:** This is a study of how air pollutants impact the rates of hospitalization in the Kaiser Hospitals located in the Central Valley. This study should help clarify the role that particulate matter plays in cardiovascular and respiratory illness in the region.
- **Vulnerable Populations Research Program:** We are currently planning several studies as part of our vulnerable populations health research initiative. The focus of this program is to determine how air pollution, including particulate matter, impacts health, and how environmental and individual health, lifestyle, and socioeconomic factors effect sensitivity to air pollution. The initial research efforts include a study of how children with asthma respond to air pollution. The study will be performed in Fresno, which has a persistent and complex particulate air pollution problem and a high rate of asthma. This study is being coordinated with major particulate air pollution monitoring efforts in the Fresno area.
- **Residential Indoor Cooking Exposures Study:** This is the most comprehensive study of cook and occupant exposures to indoor PM_{2.5}, PM₁₀, ultrafine particles, and gaseous co-pollutants during residential cooking. We will

use the data from this study to improve exposure estimates and to further explore the correlation between elevated personal exposure levels and cooking activities seen in previous studies. The data will also be used to provide guidance to the public on reducing their pollutant exposure.

- **Sources of Personal, Indoor, and Outdoor PM Exposures of Chronic Obstructive Pulmonary Disease Patients:** The main objective of this study is to quantify the contribution of outdoor air to indoor and personal PM_{2.5} exposure levels. Results of this study will enable us to better understand the link between outdoor PM_{2.5} and the health effects seen in sensitive individuals.
- **Exposure Model Enhancement:** This project will enhance the capabilities and accessibility of a model to estimate total exposure to particles and other air pollutants from all microenvironments – indoor and outdoor. The model is based on California data for pollutant concentrations, building ventilation, and human activity patterns. We will use the model to more accurately estimate Californians' exposures to particles, including toxic components such as diesel particles and metals. We can also use it to evaluate the effectiveness of different risk reduction strategies.

Air Quality Monitoring/Atmospheric Processes Research Projects

- **Biological Fingerprinting for Dust Sources:** Source apportionment models are used to relate monitored particulate species back to emission sources. Work is underway to explore the use of biochemical markers (such as fatty acids and microbial DNA) to distinguish among soil sources of airborne dust and to test these markers in source apportionment for fugitive dust. If we can distinguish the specific source of dust contributing to elevated particle levels, we can more effectively target controls to reduce emissions.
- **Remote Sensing of Ammonia:** Measuring ammonia emissions – both from sources and in ambient air – is technologically challenging. Using an advanced remote sensing device, ammonia emissions from complex sources, such as cattle feedlots or fertilized fields, can be more completely characterized. In addition, ammonia can be present in significant concentrations several hundred meters above the surface. With this ground-based remote sensing lidar technology, ammonia concentrations aloft can be measured. This technique will be used during the California Regional PM₁₀/PM_{2.5} Air Quality Study.
- **Comparison of Particulate Matter Concentrations on Weekdays and Weekends:** We are analyzing particle concentrations by day of the week to see if there are any consistent variations in concentrations between weekdays and weekends. Because of the contribution of NO_x and VOC precursors to secondary particle formation, we are also analyzing whether the variations by day of week in these precursors are evident in ambient particle levels.

Emission Inventory Development Projects

- **Ammonia Emissions From Fertilizer Application and Soils:** Working closely with the agricultural community, this project will apply various ammonia-based fertilizers to different soil and crop types in the San Joaquin Valley. The ammonia emissions that result from the fertilizer application will be quantified, and the data used to generate regional and seasonal estimates of fertilizer related ammonia emissions.
- **Commercial Charbroiling and Deep-Fat Frying Operations:** The results of this project will allow us to estimate regional and statewide particulate emissions resulting from commercial charbroiling and deep-fat frying based on the number and location of these sources, and estimates of the quantities of food cooked.
- **Dust Emissions From Vehicle Travel Over Paved Roads:** This project will use a vehicle instrumented with real-time particulate measuring devices to develop more accurate estimates of dust from vehicular travel on paved roads. This information will help provide an understanding of what activities lead to high road dust emission rates and what can be done to reduce them.
- **Emissions From Wildland Fires:** This project will provide a consistent, statewide method for estimating smoke emissions from wildland fires, incorporating satellite data, geographic vegetation data, fire modeling, and other available information. The work is being closely coordinated with staff from the California Department of Forestry and the U.S. Forest Service to take full advantage of the wildland burning expertise these agencies possess.
- **Ammonia Measurement Instrumentation:** This project will develop instrumentation which will allow characterization of ammonia plumes in near real-time. The results of the project will ultimately help to evaluate ammonia emission levels from sources that are difficult to measure using standard techniques and determine how to best reduce ammonia levels if needed.
- **Testing for Exhaust Emissions of Diesel Powered Off-Road Engines:** This project will develop test cycles for off-road equipment based on real world activity and use. In this project, a variety of diesel powered equipment will be instrumented to record their activity in the field. Based on the measured in-use activity parameters such as engine speed and torque collected during this task, an appropriate emissions testing cycle will be determined. Engines from the in-use equipment will be removed and tested for ROG, NOx, and particulate matter.
- **Duty-Cycle Development and Emission Testing of Personal Watercraft:** The objectives of the project are to: (1) instrument personal watercraft that are representative of the in-use fleet in California and collect in-use activity data; (2) derive a real-world emissions test cycle; and (3) perform emissions tests (including particulate matter) using the cycle developed during this study.

- **Particulate Emissions from Marine Outboard Engines, Personal Watercraft, and Small Off-Road Equipment:** The purpose of this contract is to: (1) develop a sampling methodology for measuring PM emissions from outboard marine and personal watercraft engines; (2) measure PM (including PM_{2.5}) and polycyclic aromatic hydrocarbon (PAH) levels from outboard marine, personal watercraft, and two-stroke, small off-road engines; and (3) determine particle size distribution and mutagenic toxicity of PM from these engines.
- **Emissions Testing of Low-Emitting Two-Stroke Utility Engines for Criteria Pollutants, PM₁₀ and PM_{2.5}:** During this project, low-emitting, two-stroke engines will be tested in a brand new condition and after several hours of usage in order to evaluate how emissions change with usage. Testing will include the measurement of particulate matter and other criteria pollutants.
- **Characterization of Particulate Matter Emissions from Motor Vehicles:** In November 1999, we began an 18-month study to measure ambient emissions of ultrafine particles (less than 0.1 microns) and nanoparticles (less than 0.05 microns) from motor vehicles. Measurements will be made on and near roadways where concentrations are expected to be highest. Both the physical and chemical attributes of particulate matter emissions from gasoline and diesel vehicles will be characterized, with an emphasis on ultrafine and nanoparticles.
- **Heavy-Duty Vehicle Chassis Dynamometer Testing at Los Angeles Metropolitan Transit Authority (MTA) Facility:** ARB is taking over the heavy-duty vehicle chassis dynamometer testing facility originally managed by the MTA. This facility will be used to perform both engine and chassis based emissions tests (including PM_{2.5}) of heavy-duty vehicles on a regular basis. Data will be used to update the emissions inventory.
- **Ammonia Emissions from Motor Vehicles:** We are investigating ammonia in motor vehicle exhaust as a significant contributor to secondary pollutant formations.

Air Quality Modeling Research Projects

- **Particulate Matter Modeling Improvements:** We are currently evaluating potential particulate matter models using data collected during a 1995 field study in central California. We have applied ARB's urban airshed model to simulate a January 1995 episode and found limitations in the model's ability to accurately simulate the formation of secondary organic particles. We have already started a research contract to address this issue as discussed below. We are also planning a collaborative project with the University of California at Davis to improve the way we model chemical reactions in the atmosphere and to make other improvements to the model. In the near future, we will evaluate the same episode with an updated version of the model.

- **Atmospheric Model Development:** This research project is to develop the next generation of models to better simulate the atmospheric reactions among precursors that form secondary particles. The model will include, for the first time, treatment of inorganic and organic constituents simultaneously. This research is crucial to our ability to model both the inorganic and organic fractions of PM_{2.5} and, therefore, to construct comprehensive photochemical models for attainment plans.

Control Strategy Development and Implementation

- **Evaluation of Technologies to Meet Future Diesel Off-Road Engine Emission Standards:** The purpose of this project is to evaluate potential technologies that could be used to meet future lower NO_x and PM emissions standards for diesel off-road engines.